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Changes in Masticatory Performance Before and During Early Orthodontic Treatment

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CHANGES IN MASTICATORY PERFORMANCE BEFORE AND DURING EARLY ORTHODONTIC TREATMENT

BY

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AUTOBIOGRAPHY

Philip S. Markin was born in Baltimore, Maryland, September 9, 1941. He graduated high school from Baltimore City College in June 1959. He received his Bachelor of Science degree in June 1963 from the University of Maryland. In June 1966, he received his Doctor of Dental Surgery degree from the University of Maryland. He served as a Captain in the United States Army Dental Corps from August 1966 until January 1969. Following his separation from the service, he practiced general dentistry until June 1970. He was married November 1969 to the former Susan Gail Finkelstein. He was accepted into Loyola University Graduate School of Dentistry, Department of Orthodontics, in June 1970.

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION AND STATEMENT OF THE PROBLEM

There have been relatively few studies published which deal with masticatory performance and only one of these has dealt with masticatory performance of orthodontic patients. This was a cross-sectional study of different types of malocclusions.

The purpose of the present study is to determine if early orthodontic procedures alter the pattern of mastication as determined by particle size, habitual chewing time and bolus size.

CHAPTER II

REVIEW OF THE LITERATURE

1. Masticatory Performance:

Lehmann (1900) and Gaudenz (1901) were the first to make observations on masticatory efficiency. Their studies tested various types of foods and the degree to which they were masticated before reaching the swallowing threshold. A single sieve with 1 mm. openings was used to strain the particles recovered. Particle size was then determined.

Paulsen (1920) studied the mechanical breakdown of food when occlusion was disturbed by artificial high crowns placed on the mandibular first molars. It was found that food breakdown was decreased when masticatory function was impaired.

Clausen (1921) observed the mechanical breakdown of food with ten teeth missing and then with a partial denture replacing the missing teeth. He reported that the partial denture aided in the mechanical breakdown of food.

Christiansen (1923) was one of the first men who tried to develop a method to test mastication. He used cylindrical pieces of coconut and hazel-nuts as the test foods. The method employed to measure masticatory performance was to give the subject measured amounts of test food and have them chew for fifty strokes. The particles were then washed out of the mouth, passed successively through four sieves (5, 10, 20 and 30 meshes per centimeter) and then dried. The results of the experiment were expressed as the proportion of each portion compared to the four together, thus giving a percentage of the total weight recovered. Due to the fact that only seven subjects were used in this study, it is very possible that the results obtained were due to chance.

Juul (1932) investigated the masticatory powers in children with normal and abnormal occlusion. He used a method similar to Christiansen's. The results of the study show that the chewing powers in children with poor occlusion are on the average worse than those with normal occlusion. Both the degree of malocclusion and statistical evaluation of the evidence were lacking in this study.

Gelman (1932) studied the masticatory powers in adults. He used sweet almonds as a test food, had the subjects chew for a fixed time period, dried the fractions recovered over a water bath (rather than in a drying-cupboard at 100° C. as had previously been done), and then used a single strainer with round holes 2.4 mm in diameter. The author's conclusion of this study was that loss of six to nine articulating pairs of teeth (an average of seven pairs) decreases the mastication powers by half. Again, in this study, statistical evidence was inadequate to substantiate the results obtained. There were no figures for individual cases and no calculations concerning the standard error were made.

Ascher (1938) also studied masticatory performance in adults. He used the same basic procedure as Christiansen, except that he used Brazil-nuts as his test food. He divided his subjects into three groups: the first group had complete sets of dentition; the second group had slightly defective dentition--up to six mastication units missing (one pair of molars antagonizing one another was regarded as a unit and other pairs of teeth were half-units); and the third group had defective dentition--more than six masticatory units missing. The results show that with progressively worse dentition, the fraction on the coarsest strainer was increased. The author concluded that with the loss of more than six masticatory units, a prosthetic replacement was necessary. This study also lacked statistical analysis.

In Sognnaes' review on masticatory efficiency (1941), he stated that previous studies had not been extensive enough nor had they been sufficiently well controlled to allow any definite conclusions.

Dahlberg (1942) conducted the most thorough test and analysis of mastication until that date. He first set out to determine a satisfactory test food. After testing different materials, a 15% gelatin with 5% barium sulphate with a red coloring matter added was chosen. This material was cut into standard size pieces for testing. The straining apparatus consisted of a thick tube with ten strainers with the diameter of the holes going from 10 to 1 mm, and 1 mm between each hole. Water was rotated on the strainers for six minutes, with rotations reversed every forty-eight seconds with twelve second intervals. The degree of reduction was established by counting the particles in the first seven strainers and by measuring sedimentation of the last three strainers. A uniform expression for the degree of reduction was obtained by calculating the total area of the particles composed in the test portion after it had been chewed. A mastication coefficient was computed using the values obtained for volume and surface area (yields the square cm. of area per cubic cm. of volume in the test portion). This coefficient gives an expression for the portion's degree of reduction.

Using the methods that he worked out, Dahlberg investigated the masticatory efficiency of people of different ages and sex, with good teeth, defective teeth, and with full dentures. Classification of teeth was done with regard to the number of teeth present, the teeth in occlusion, and according to a point scale. In order to characterize sets of teeth, a contact coefficient was worked out. Sets of teeth were then grouped into four classifications (extremely good, good, bad, and extremely bad) according to the number of occlusal contacts. Tests were then conducted recording the number of chews needed until reaching swallowing threshold. Results showed that poor sets of teeth were not compensated for by a greater number of chews. It was seen that seven-year olds seem to take fewer chews than the other groups. It further was noted that an individual chews a varied number of times in repeated tests. This indicated that individuals have different chewing habits and these habits were independent of the chewing results obtained. When mastication coefficients were obtained on persons with varying sets of teeth, it was seen that differences in masticatory effectiveness ran parallel with deterioration of the sets of teeth. An important observation was noted in this test: the effect of the teeth in a deteriorated set was not compensated for by increasing the number of chews, but some compensation was seen by an increased skill in the management of the bolus. The study also investigated the effect of increased number of chewing strokes. This was done by allowing the subjects to chew twenty and then forty times respectively. The result showed that by chewing twice as many times (forty strokes), the masticatory efficiency increased only 20 to 30%.

This study also discussed the important role of the different variables in mastication. It was concluded that different chewing habits and differences in the sets of teeth seemed to play about equal parts for the variation in the masticatory effect. Differences in skill in chewing and in the anatomy of the teeth and jaws were observed as important variables. Finally, it was noted that individual differences in repeated tests indicated another important variable.

Yurkstas (1948) measured the effective contact area in mastication. It was concluded that although the area measured represented only a small fraction of the total occlusal surface area, this area probably accurately represents the fraction of total area which is actively involved in mastication. He based this conclusion on the fact that the areas measured correlated well with the masticatory performances of the individuals tested. Results obtained showed that the first molar provided 36.7% of the total effective area in a complete dentition. The percentages of 27.9, 15.4, 12.9, and 8.1 were obtained for the second molar, third molar, second premolar, and first premolar, respectively. The study also considered whether the loss of a tooth would change the effective occlusal contact area between the remaining teeth. The findings indicated that the total area is reduced most by the loss of the first molar, less by loss of the second molar, and least by loss of the third molar. The data also showed that there is no important change in the area of remaining teeth as teeth are lost.

Yurkstas (1950) studied the value of different test foods in estimating masticatory ability. Requirements established for a test food were that it should be homogeneous, common, inexpensive, and palatable. It was further stated that the food should be difficult enough to masticate to ensure that a normal dentition should receive a higher rating than a deficient dentition. The food should be easily separated into fractions according to particle size. Further, the quantities required in the test should be small enough to avoid physical or psychological fatigue of the subject. Peanuts fulfill most of the requirements set up in this study. In comparing different test foods, it was found that there was a high level of correlation ($P<.05$) between peanuts, carrots, and ham. This indicated that these test foods provided information that concerned similar phases of mastication.

Manly (1949) published a study that had as its major objective the development of a method for measuring masticatory performance and efficiency. He stated that there were certain principles that should be employed in designing a test for mastication. The test food should be one that is normally consumed. The difficulty in chewing should be enough to guarantee that individuals with normal dentition will get a higher rating than individuals with deficient dentition. If there is any selective action by the normal dentition and missing from the deficient dentition, this should be taken into account. By this, it is meant selection of hard foods versus soft, selection of small pieces versus large, etc. The test should be precise, the method simple, rapid and inexpensive. Manly's test of masticatory performance was based on the percentage of masticated peanuts which would pass through a 10-mesh screen after being chewed for twenty strokes. It was found that the size of the portion does not influence the masticatory performance. The manner in which efficiency was calculated was counting the number of strokes required to reach a desired degree of food pulverization.

Manly followed with another study (1951) that considered the factors that effect masticatory performance and efficiency among young adults. The three factors that were considered were the food platform area, the tooth units in occlusion, and the mesio-distal length of molars. The results indicated that the food platform area and the size of the molars were the most important determinants for chewing ability among adults with normal or defective natural dentition.

Shiere (1952) reported the effect of changing dentition on masticatory function. The masticatory efficiencies of children averaged about half that of adults who had comparable dentition, except that third molars were present in adults. It was found that in children, first and second permanent molars did not improve masticatory function immediately after eruption, but efficiency gradually increased three or four years thereafter. It was also found that efficiency declined after ten years of age and rose again by fourteen years of age. The reason for this probably is because this is the time required for the newly erupted teeth to become functional. Malocclusions other than Class III were reported similar to normal cases in their average masticatory function. This study also reported no difference in the efficiency of males and females with similar ages.

Yurkstas (1953) studied the effect of missing teeth on masticatory performance and efficiency. Peanuts were used as the test food and masticatory performance was determined by the amount of test food which passed through a 10-mesh screen after twenty masticatory strokes by the subject. Results of the study showed that loss of only the first molar reduced chewing efficiency about 35%. Loss of the second and third molar resulted in a decrease of 44% of masticatory efficiency. When the first and third molars were lost, masticatory efficiency dropped 66%. However, statistics from this study indicate a wide variation in masticatory efficiency that occurs with the same number of teeth in occlusion. For example, in people with missing third molars, there was a range in masticatory efficiency from 10 to 165 units. This wide range in each individual indicated that counting the number of teeth in occlusion was of little value in determining masticatory efficiency.

Manly (1953) reported what appears to be the only study published concerning masticatory function of children with orthodontic disturbances. This study was cross-sectional and considered factors such as age, sex, numbers of posterior teeth in occlusion, food platform area, maximum force, and the side of mastication. The test for masticatory efficiency consisted of having the subject chew three gram portions of peanuts and carrots for twenty strokes. The samples of chewed food were poured through a 10-mesh screen, and the volumes of food passing and remaining on the screen were read after centrifuging. It was found that the presence of an orthodontic appliance influenced chewing ability. Both the side preferred for mastication and the sex of the patient did not relate to masticatory ability. An important influence on chewing ability was found to be the number of posterior teeth in occlusion. It was found that the first premolar had little or no contribution while the first molar was seen to be the most important tooth for mastication. It was stated further that the pulverization of foods at the time of swallowing was related to chewing ability; however, low masticatory efficiency just meant that poorly pulverized food was swallowed.

Allgood's thesis (1963), "Variability of Masticatory Performance and Swallow Threshold in Man" contains an extremely thorough technique for measuring masticatory performance. Peanuts were used as the test food and bolus size and swallow threshold were determined by each subject. Both were recorded. When the test was run a second time, instead of swallowing, the bolus was expelled. The particles were divided into fractions by washing them through a series of five sieves and filter paper. Allgood concluded that the individuals tested were relatively constant in the choice of bolus size, masticatory strokes, and particle size at swallow threshold, but large differences existed among individuals. One of the advantages of this test is its normal functional approach. Each subject chose his own bolus size and chewed it for his own length of time. This recognized the built-in habitual differences among subjects. Also, it gave each subject a chance to change his mind each time tested. Subconsciously, an orthodontic patient undergoing treatment may favor his teeth by taking a smaller bolus or chewing for a longer period of time.

2. Orthodontic Considerations:

Tweed's definition of leveling is the correction of rotated teeth and the gaining of good arch form. In order to gain good arch form, any crowding present must be eliminated and the tooth or teeth in question must be brought into the alignment of the patient's arch. Usually, during this stage of treatment, another objective is to begin to open the patient's bite. This is accomplished two ways: by depressing the mandibular anterior teeth and by tipping back the posterior teeth, so that the mesial marginal ridge of the tooth is higher than the distal marginal ridge. When this has been accomplished, theoretically, only the mesial half of the opposing teeth will occlude with one another. The leveling procedure is carried out by using a series of round wires, with whatever loop systems are necessary for that particular patient. The wires progressively increase in size from .016 inch to .020 inch. As previously stated, during the leveling stage, the posterior teeth are tipped back. This is done both to open the bite and to develop anchorage so that canines can be retracted.

Retracting canines in the Tweed technique can be accomplished in various ways. Of course, the method depends entirely on the patient's particular need; whether minimum, moderate, or maximum retraction is necessary. Canines can be uprighted by means of compressed loops, or they may be moved bodily by means of coil springs or headgear. All three of these methods of canine retraction are used routinely in the Tweed technique, depending on the patient. Often, during canine retraction, the occlusion is in its worst state. Besides the fact that there are spaces between the anterior four teeth and the canines, the posterior teeth are tipped back and are only articulating on a small portion of their occlusal surfaces.

These two stages, leveling and canine retraction, are distinct steps in the Tweed technique, as well as in most other orthodontic techniques, and it is convenient to use these stages as intervals to measure changes in masticatory performance.

CHAPTER III

METHODS AND MATERIALS

1. Introduction:

To establish the accuracy and reliability of the method, a set of tests was conducted using five second year graduate orthodontic students. The tests on the graduate students were conducted at two different time periods to verify the relia-bility of the testing procedures and techniques.

Eleven patients who were about to receive orthodontic treatment in the Orthodontic Department at Loyola University were selected as subjects for this study. Their ages ranged from eleven to fifteen years.

The subjects all had the same type of malocclusion: Class II division 1. Further, they all were diagnosed as requiring extraction of their four first premolar teeth. An attempt was made to have most of the subjects treated by the same orthodontic technique. Nine out of the eleven subjects were treated using the Tweed technique.

Before any experimental data was collected, initial records were taken on each subject. These records consisted of a medical history, a dental examination, twelve color transparencies, cephalometric x-rays, panorex x-ray, a carpal index, and alginate impressions for plaster casts of the teeth.

The first experimental records were obtained shortly after the final diagnosis that the patient would require removal of the four first premolar teeth, and would probably be treated by the Tweed technique. Records were taken a second time, after it was decided that each subject's teeth were level, according to Tweed standards. A third set of records were taken when the canine teeth had been retracted one-half the distance of the extraction site.

2. Design of the Experiment:

The method of testing and measuring masticatory performance was patterned after that of Allgood (1963). Each subject was seated in a chair and was presented with a can of peanuts* and instructed to take as many peanuts as he normally does when eating a mouthful of peanuts. The peanuts chosen were then placed in a paper cup and weighed. A second batch of peanuts was then weighed and placed in a similar paper cup. The peanuts were returned and the subject instructed to place all of them in his mouth, to chew the nuts, then to swallow them. The subject was informed that he should signal, by raising his

*Planters Salted Peanuts-13 oz. can

hand, when he was about to swallow. Without the subject being aware of it, his swallowing threshold was being timed in 100ths of a minute. After the subject had swallowed the peanuts, he was given a cup containing 100 ml. of water and was instructed to rinse his mouth carefully. The rinsings were collected in a beaker. The mouth was then inspected to make certain that no large particles were still present.

The same test was run a second time, with the same weight of peanuts used. The subject was instructed not to swallow any of the peanuts and to continue chewing until he was told to stop. The subject chewed the second batch of peanuts for the same amount of time as he had indicated was his swallowing threshold in the first test. The peanuts were expelled into a beaker. The subject again rinsed his mouth with 100 ml. of water, and the rinsings were collected in the same beaker as the peanuts. Again the mouth was inspected for any large particles that might have remained.

An attempt was made to test each subject at a time during the day in which he would not be especially hungry (not near lunch or dinner time). It was felt that subconsciously, he might take more peanuts than under normal conditions, and that his chewing pattern would be altered.

The beaker of recovered particles was then inverted over a series of five sieves and washed with 5000 ml. of water. The grades of the sieves according to U. S. P. standards were 10, 20, 40, 80, and 170. The size of the openings of each sieve was as follows: #10, 2.00 mm. or .0787 inches, #20, 841 microns or .0331 inches, #40, 420 microns or .0165 inches, #80, 180 microns or .0070 inches, and #170, 88 microns or .0035 inches. The particles which remained on each sieve were then recovered by washing them off the sieve, and were strained by means of a Buchner funnel under suction. The particles remaining on their respective pieces of filter paper were then placed in a pan, along with a control of 10 grams of peanuts on a piece of filter paper, and allowed to dry in an oven set at 60° C. for twenty-four hours.

The dried peanuts that were used as a control were then weighed to determine how much moisture had contributed to the original weight. The particles from each sieve were then weighed and the amounts recorded. Percentages of each particle size were calculated by dividing the total recovered weight by the weight of the particles on the sieve in question.

As previously mentioned, the tests were conducted twice after the initial test. The second measurement period was after leveling the teeth, and the third measurement period was half-way through canine retraction. It was noted on each subject's record if the teeth were tender at the time of each test. Archwires were removed before conducting tests at these stages, since it was felt that the archwires would trap large particles and distort the results of the study.

The following statistical analyses were performed on the data collected from the three testing periods for the eleven subjects: an analysis of variance was performed to determine if there were any statistically significant differences for fractions of peanuts recovered attributed to individuals, sieves, testing periods, and interactions therein.

Paired "t" tests were conducted to analyze any significant differences between chewing times before and during treatment and between bolus size chosen before and during treatment.

For each measurement period, coefficients of correlations were determined between chewing time and fraction recovered on each sieve, bolus size and fraction recovered on each sieve, and bolus size and chewing time. Finally, coefficients of correlation were determined for chewing time divided by bolus size and fraction recovered on each sieve.

CHAPTER IV

FINDINGS

The pilot study, which was conducted along with the actual experiment, had the purpose of verifying the accuracy and reliability of the testing procedure. Paired "t" tests were conducted to analyze any significant differences in any of the five screen profiles in the two tests conducted on five graduate students. The results of the "t" tests reveal that there was no statistically significant difference between any of the five screen profiles ($P > .05$). From these results, the method of testing was considered reliable.

A summary of the means and standard deviations for bolus size, chewing time, and percent recovery on each sieve of the three testing periods is presented in Table 1.

For each measurement period, coefficients of correlations were determined between chewing time and fraction recovered on each sieve (Table 2).

No statistically significant correlation was found between chewing time and the fraction recovered on each sieve. It does not appear that chewing time was related to chewing performance.

TABLE 1

Means and Standard Deviations
From the Three Tests

	Test #1	Test #2	Test #3
Bolus (grams)			
mean	9.6	9.4	9.3
sd	±3.7	±2.1	±2.8
Time (100ths of minute)			
mean	40.6	48.3	44.4
sd	±14.9	±18.2	±11.1
% Recovered on Sieve			
Sieve #1			
mean	40.5	45.6	43.1
sd	±16.9	±15.1	±18.9
Sieve #2			
mean	22.5	19.2	19.5
sd	±5.1	±4.3	±5.1
Sieve #3			
mean	14.7	13.7	14.4
sd	±4.6	±4.3	±5.0
Sieve #4			
mean	11.8	11.3	12.0
sd	±4.5	±3.6	±4.2
Sieve #5			
mean	10.5	10.2	10.9
sd	±4.4	±3.6	±3.8

TABLE 2

Coefficients of Correlations (r) between Chewing Time and Per Cent Recovered on Each Sieve

	Time (Test #1)	Time (Test #2)	Time (Test #3)
Sieve #1	r=.3734	r=-.181	r= .063
Sieve #2	r=-.024	r= .421	r= .107
Sieve #3	r=-.450	r= .128	r=-.098
Sieve #4	r=-.477	r= .005	r=-.135
Sieve #5	r=-.454	r= .084	r=-.150

TABLE 3

Coefficients of Correlations Between Bolus Size And the Per Cent Recovered on Each Sieve

	Bolus (Test #1)	Bolus (Test #2)	Bolus (Test #3)
Sieve #1	r= .085	r= .503	r= .866*
Sieve #2	r=-.631*	r=-.200	r= .852*
Sieve #3	r=-.937*	r=-.529	r=-.812*
Sieve #4	r=-.819*	r=-.588*	r=-.885*
Sieve #5	r=-.814*	r=-.647*	r=-.663*

*-$P<.05$

Coefficients of correlations were determined between bolus size and the fraction recovered on each sieve (Table 3).

There was statistically significant correlations throughout the three tests between bolus size and fraction recovered on each sieve ($P<.05$). These results indicated that the larger the bolus size chosen by the subject, the less the percentage of particles were recovered on the finer sieves.

Coefficients of correlations were determined for chewing time divided by bolus size and the fraction recovered on each sieve (Table 4).

For the most part, there was a statistically significant correlation throughout the three tests ($P<.05$) between time divided by bolus and the fraction recovered on each sieve. This was especially true in the third test. It appeared that if the subjects chewed longer and took less peanuts, a higher percentage of particles were recovered on the finer sieves.

Coefficients of correlations were also determined for bolus and time (Table 5).

There was statistically significant correlation ($P<.05$) only for the first test. The other two tests, however, did not show significant statistical correlation. It should be noted that in all three periods the correlation was positive, indicating the larger the bolus chosen, the longer the chewing

TABLE 4

Coefficients of Correlations Between Time Divided By Bolus and the Per Cent Recovered on Each Sieve

	Time/Bolus (Test #1)	Time/Bolus (Test #2)	Time/Bolus (Test #3)
Sieve #1	r=-.526	r=-.441	r=-.663*
Sieve #2	r= .654*	r= .522	r= .767*
Sieve #3	r= .430	r= .419	r= .586*
Sieve #4	r= .374	r= .863*	r= .586*
Sieve #5	r= .421	r= .404	r= .622*

*-P<.05

TABLE 5

Coefficients of Correlations for Bolus and Time

	Test #1	Test #2	Test #3
Bolus and Time	r=.634*	r=.168	r=.194

*-P<.05

time.

Paired "t" tests were conducted to analyze any significant differences between chewing times before and during treatment. Comparing tests one and two, one and three, and two and three, revealed no statistically significant differences ($P > .20$).

Paired "t" tests were also conducted to analyze any significant differences between bolus sizes before and during treatment. As in the previous "t" tests, one and two, one and three, and two and three were compared. No statistical differences were seen ($P > .20$).

Finally, an analysis of variance was performed to determine if there were any statistically significant differences for fractions of peanuts recovered attributed to individuals, sieves, testing periods, and interactions therein (Table 6).

From the analysis of variance, it was seen that the only variance of statistical significance at the $P = .05$ level was for sieves. However, the interaction of subjects showed a probability of $0.20 > P > 0.10$. It is possible that had the sample size been larger, a statistically significant difference could have been demonstrated.

A separate analysis of variance was performed to see if there were any statistically significant differences for tests,

Table 6

Analysis of Variance Comparing Per Cent Recovery For Subjects, Tests, Sieves, and Interactions

Source	D.F.	Sums of Squares	Mean Square	F	P
Subjects	10	--	--	--	--
Tests	2	--	--	--	--
Sieves	4	23355.94	5838.99	54.83 (C/AC)	P<.01
Interactions					
Subjects & Test	20		--	--	--
Subjects & Sieves	40	4259.71	106.49	1.16 (AC/ABC)	20>P>.10
Tests & Sieves	8	329.54	41.19	.45 (BC/ABC)	P>.20
Residual	80	7314.64	91.43	--	--
	164	35259.83			

subjects and interactions therein for Sieve #1 (Table 7) because most of the variance in the sieves was within the coarsest sieve (Sieve #1). This analysis of variance showed significant variance between subjects at $P<.01$ level.

TABLE 7

Analysis of Variance Comparing Per Cent Recovery For Subjects, Tests and Interaction in Sieve #1

Source	D.F.	Sums of Squares	Mean Square	F	P
Runs	2	229.13	114.57	1.32	P>.20
Subjects	10	7296.20	729.62	8.41	P<.01
Interaction	20	1736.11	86.80	--	--

CHAPTER V

DISCUSSION

It has been stated by various authors that certain factors influence masticatory performance. Among these factors are missing teeth, number of teeth in occlusion, number of occlusal contacts, age, sex, and habits. Other factors, namely orthodontic factors, consist of orthodontic classification and method of treatment. What is meant by orthodontic classification is the ability of a Class I to masticate versus a Class II division 1, or a Class II division 1 versus a Class III. The method of treatment might play a role because a light wire technique is theoretically more gentle to the teeth than a heavy edgewise wire technique.

It generally has been concluded that as the occlusion deteriorates, so does the masticatory performance. By this, it was meant that with more missing teeth and with the occlusal contacting areas reduced, masticatory performance was reduced. Yurkstas reported that particular teeth were responsible for certain percentages of chewing performances.

Yurkstas and Manly found that the number of teeth in occlusion were not nearly as important as the number of occlusal contacts in measuring masticatory performance.

Manly found that between the ages of ten and twelve, there was an increase in masticatory performance, but from twelve to sixteen, the performance remained essentially the same.

Shiere and Manly both determined that sex was not a significant factor in masticatory performance.

In the present study, the significant factors that influence performance were controlled in the following manner: all of the subjects were diagnosed as Class II division 1 malocclusions. They all required the extraction of the first four premolar teeth. Nine out of eleven of the patients were treated by the Tweed technique of orthodontics. During the first testing period, none of the subjects had had any teeth extracted. For the second and third testing periods, all of the subjects had the same teeth extracted (the first four premolars). Only one subject was below the age of twelve; she was eleven.

One factor that proved critical was the habitual chewing pattern of each subject. Dahlberg was the first to mention the significance of chewing habits. He said that individuals have different chewing habits and these habits were independent of the chewing results obtained. Dahlberg observed that the effect of the teeth in a deteriorated set was not compensated for by increasing the number of chews but some compensation was seen by an increased skill in the management of the bolus. Allgood also recognized the importance of the habitual differences among subjects. His study allowed each subject to choose his own bolus size and to chew it for whatever time needed to reach swallowing threshold. Allgood concluded that the individuals were relatively constant in their choice of bolus size and swallow threshold, but large differences existed among individuals. He also made another important observation: individuals were relatively constant in their particle size at swallow threshold.

The present study recognized the important role that habit plays in mastication. Rather than compare the ability of each subject to perform a standard test, each subject was allowed to determine the size of the bolus and his own chewing time. This freedom allowed each subject resulted in an important conclusion: each subject chews to his own particular particle size before swallowing.

During the course of the present study, the occlusion of the subjects was significantly altered. Of course, in the first testing period each subject still had all of his teeth and his original malocclusion. Also, the orthodontic appliance had not been placed yet. For the second testing period, the subjects were fully banded and had had archwires in place. Their first four permanent premolars had been extracted and the remaining teeth were fairly well aligned (not necessarily well inter-digitated). In the third testing period, the occlusion was similar to that in the second testing period except that the canine teeth had been retracted half-way posteriorly.

During the study, it was noted that for the first testing period there was some apprehension on the part of the subjects toward the investigation. Because of tooth movement during the second and third testing periods, there was some complaint about sore teeth. Among the subjects who did not have this complaint, there still might have been, subconsciously, some apprehension in chewing on "tender" teeth.

There were also some variables which either were not measured or could not be measured which could influence chewing performance. The exact amount of occlusal surface in contact with opposing teeth was not measured. Neither was biting force measured in this study. Another variable, bolus manipulation, is unmeasureable. By bolus manipulation, it is meant how the subject moves the bolus around in his mouth and over his teeth with his tongue and lip musculature. As Allgood stated, it is important not to disturb an individual's chewing pattern by making him perform a standard test.

In spite of all these variations, the individual's sieve profiles remained essentially the same. In complete agreement with Allgood, it was found that an individual chews subconsciously to a consistent particle size before swallowing. In order to reach their own individual particle size, the subjects compensated by either changing bolus size or chewing time. This was not demonstrated statistically because of the individuality of each subject; there was no consistent pattern for the subjects as a group. A consistent finding throughout the study was that as bolus size increased, the ability to masticate to finer particle size decreased. There also seemed to be trend during the second and third measurement period for chewing time to increase.

All of these facts point to the conclusion that as long as the subject is allowed to pick his own bolus size and chew until his individual swallow threshold is reached, particle size will remain essentially the same. It can therefore be speculated that even after treatment, with excellent occlusions, these same subjects would chew to the same particle size. What this means is that the ability to take a larger bolus size and chew it to the particle size required to swallow is possible. The other possibility is that a smaller bolus could be pulverized more quickly to swallow threshold size. Another possibility is that by significantly improving the occlusion and, hence, increasing the number of occlusal contacts, it can be speculated that the individual's particular particle size could be reached without changing bolus size and chewing time. By this it is meant that less masticatory effort would have to be put into each chewing and swallowing routine. Essentially, masticatory performance (the breakdown of a bolus to particle size) remains the same despite the conditions that the individual is subjected to.

CHAPTER VI

SUMMARY AND CONCLUSION

A method of testing masticatory performance in orthodontic patients was described. The reliability of this procedure was statistically proven. This method was used to determine if early orthodontic procedures alter the masticatory performance as it relates to bolus size and chewing time.

The testing procedure had the following sequence: the subject chose as many peanuts as he normally chews in a mouthful. The peanuts were weighed and a second amount of peanuts, equal to the first amount chosen by the subject, was determined. The subject chewed the first batch of peanuts and signaled when he was about to swallow. The chewing time of the subject was recorded. After rinsing his mouth thoroughly, the subject was given the second batch of peanuts and instructed to chew them but not to swallow. When the subject's chewing time had expired, instead of swallowing, he expelled the bolus of peanuts into a beaker and rinsed his mouth carefully. The rinsings were also expelled into the beaker. The beaker was then inverted over a series of five sieves, decreasing in coarseness and the particles washed with a measured amount of water. The particles which remained on each sieve were then recovered and dried. The percent recovered on each sieve was then calculated.

The subjects were tested three times during the study. The first test was conducted before extraction of teeth was performed and before the orthodontic appliance was constructed and placed in the mouth. The second and third tests were conducted during active orthodontic treatment. No significant difference was found in masticatory performance (as evaluated by recovery on the various sieves) between any of the three tests.

A significant feature of the testing procedure was that it allowed for the habitual pattern of each individual subject. Rather than compare the subjects to a standard bolus size and chewing time, each subject chose his own bolus size and chewing time for each test. This allowed for any changes the subjects might make to compensate for their change in occlusion.

A consistent finding in the study was that as bolus size increased, the ability to masticate to finer particle size decreased. There also seemed to be a trend indicating that at the second and third measurement periods, the subject's chewing time increased. There doesn't seem to be any consistent pattern to the changes in bolus size due to treatment.

It was found that in spite of the change in occlusion, teeth missing due to extraction, and the presence of an orthodontic appliance, the individual's sieve profile remained essentially the same. It was concluded that an individual chews to a consistent particle size despite the variables with which he may be confronted.

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APPENDIX TABLE I

Individual Data for Bolus Size, Chewing Time, and Per Cent Recovery on Each Sieve for the Testing Period #1

Subject	Time	Bolus	Per Cent Recovered on Sieve in Test #1				
			A	B	C	D	E
1	74	17.1	60.4	17.5	8.6	7.5	6.1
2	39	10.0	55.4	18.2	9.9	8.4	8.2
3	35	6.5	34.9	20.4	16.5	14.9	13.3
4	29	8.5	45.1	21.5	14.1	10.6	8.7
5	44	8.5	27.4	29.4	18.1	13.6	11.5
6	33	8.5	21.4	28.5	20.3	15.9	14.2
7	31	5.5	13.7	23.2	22.2	21.2	19.8
8	35	10.0	48.0	22.5	13.4	9.8	6.3
9	62	7.5	29.9	31.6	16.1	11.2	11.2
10	21	5.5	25.1	23.7	19.3	16.3	15.6
11	46	17.0	72.5	12.7	6.6	4.2	4.0
12	53	11.0	44.5	22.3	14.4	10.2	8.5
13	27	9.0	47.8	20.5	12.6	9.9	9.2

Sieve Mesh Size - A(2000 microns), B(841 microns), C(420 microns), D(180 microns), E(88 micron)

Time - 100th of a minute

Bolus - grams

APPENDIX TABLE II

Individual Data for Bolus Size, Chewing Time and Per Cent Recovery on Each Sieve for the Test Period #2

Subject	Time	Bolus	Per Cent Recovered on Sieves in Test #2				
			A	B	C	D	E
1	56	9.0	64.6	12.7	8.8	7.1	6.8
2	45	9.0	51.1	19.8	12.0	9.5	7.5
3	30	7.3	35.6	20.0	16.4	14.0	14.5
4	39	13.0	49.9	19.2	12.4	10.0	8.5
5	61	9.4	60.2	15.6	9.5	7.3	7.3
6	45	8.5	27.5	23.7	19.8	16.9	12.1
7	61	7.3	20.2	25.0	21.6	16.7	16.5
8	49	11.0	62.6	14.4	9.3	7.4	6.2
9	93	10.5	29.2	27.0	16.8	13.6	13.4
10	23	7.2	42.7	17.0	14.1	13.5	12.7
11	40	13.2	61.0	16.7	9.3	7.2	5.8
12	38	7.8	42.3	19.6	14.6	12.3	11.1

Sieve Mesh Size - A(2000 microns), B (841 microns), C(420 microns), D(180 microns), E(88 microns)

Time - 100th of a minute

Bolus - grams

APPENDIX TABLE III

Individual Data for Bolus Size, Chewing Time and Per Cent Recovery on Each Sieve for the Testing Period #3

Subject	Time	Bolus	Per Cent Recovered on Sieves in Test #3				
			A	B	C	D	E
1	38	6.5	47.7	19.8	12.3	10.2	10.0
2	44	9.0	48.2	18.3	12.7	10.7	10.1
3	41	10.0	41.9	19.2	14.7	12.4	11.8
4	25	10.5	49.1	17.8	13.1	11.0	9.1
5	35	7.0	28.5	21.8	19.1	15.5	15.2
6	39	6.0	18.0	25.1	20.1	18.9	17.3
7	46	7.4	20.4	25.4	22.9	17.5	13.8
8	60	12.8	54.4	18.6	10.9	9.0	7.1
9	64	7.0	27.7	26.2	17.7	14.6	13.9
10	51	12.1	64.1	13.3	8.8	7.1	6.7
11	45	14.0	73.8	9.4	6.5	5.3	5.0

Sieve Mesh Size - A(2000 microns), B(841 microns), C(420 microns), D(180 microns), E(88 microns)

Time - 100th of a minute

Bolus - Grams

APPROVAL SHEET

The thesis submitted by Dr. Philip Sheldon Markin has been read and approved by members of the Department of Oral Biology.

The final copies have been examined by the Director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

5/15/72

Date

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